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TRACE METAL EVALUATION OF GROUNDWATER IN NKONGSAMBA, MUNGO DIVISION, LITTORAL REGION, CAMEROON

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ABSTRACT

Increased urbanization and agricultural activities have a potential for trace metal contamination, therefore the trace metal evaluation of groundwater in Nkongsamba is very important. This study investigated the trace metal content of groundwater sources; determined the health hazard and pollution risk indices; assessed the health hazard and level of risk to trace metal pollution in Nkongsamba. Measurement of 153 hand-dug wells for physicochemical parameters (pH, temperature, electrical conductivity and total dissolve solids) and chemical analysis of 10 representative groundwater samples was carried out to determine their trace metal content using Inductively Coupled Plasma Mass Spectroscopy ICP-MS. R-mode statistical analysis; Hierarchical Cluster Analysis (HCA) and Pearson's correlation analysis (PCA) of the trace metals to the physicochemical parameters was done. Four pollution hazards were estimated; the average daily dose ADD, carcinogenic risks CR, non-carcinogenic risk hazard quotient HQ and hazard index HI. Six pollution risks indices were determined: the Degree of contamination DC, Enrichment factor EF, Ecological risk factor Er, Ecological risk index RI, Pollution load index PLI, and geo-accumulation index (Igeo). The trace metals detected in groundwater in Nkongsamba and their relative abundance in decreasing order is: Ba > Fe > Zn > Mn > Sr > Ni > Cu > Co > Pb

> Cr > As > Li > Cd > V. HCA distinguishes trace metals into two clusters: Cluster 1 was divided in to two classes; class one (01) element Ba; soluble and class two (4) elements Mn, Sr, Zn, and Fe; enriched. Cluster 2; (9) elements V, Cd, Li, As, Cr, Co, Pb, Cu, and Ni; non soluble. The values of groundwater pollution hazard indices ranged; ADD (3.14286×10^{-07} to 0.0214971 mg/kg/day), CR (3.7714×10^{-05} to 0.013728), HQ (4.4898×10^{-05} to 0.588163265) and HI (0.001445 to 0.021261). The values of the pollution risk indices are DC (1.29 to 18.82), EF (0.002 to 2.61), Er (0.012 to 13.817), RI (1.767 to 26.753), PLI (0.0118 to 0.0942) and Igeo (-14.87 to 2.70). The health risk assessment qualified groundwater in Nkongsamba as unsafe and intolerable for human consumption but without carcinogenic effects. Very strong correlations were observed among some of the trace element pairs, suggesting common sources, mutual dependence and identical behaviour from provenance and during transport. These low trends might not guarantee human health due to an increasing level of environmental pollution that might be imposed by increasing human activity in Nkongsamba causing contamination of the groundwater; this demand for monitoring of groundwater sources for drinking purposes.

***Keywords:* *Trace-Elements-Evaluation, Health-Risks-Assessment, Pollution-Indices, Nkongsamba -Cameroon*.**

1.1 Introduction

Groundwater contains important minerals that are useful for human nutrition (Yuce *et al.,* 2009; Kamau *et al*., 2008; WHO, 2008), it's important for nourishment of living beings and is a reservoir for good quality water (Bhutiana *et al.,* 2016; Batabyal *et al.,* 2018). Groundwater is a major source for drinking, irrigation and industrial uses in many countries due to its instant availability and natural protection from microbial contamination (Al-Khashman *et al.,* 2014; Aghazadeh *et al.,* 2017; Selvan *et al.,* 2017; Saha *et al.,* 2018). Considerable increase in population growth and surface water contamination has made the demand for groundwater high (Hossain *et al.,* 2017; Islam *et al.,* 2014; Saha *et al.,* 2017; Bodrad-Doza *et al.,* 2019b). It is now a major concern has groundwater is contaminated by trace elements that have exceeded their background values (Ahmed *et al.,* 2004; Biswas *et al.,* 2012; Islam *et al.,* 2017; Uddin *et al.,* 2018), due to their toxic, persistence and carcinogenic nature, these trace elements may have serious adverse effects to human health (Naz *et al.,* 2016; Rahman *et al.,* 2017).

Trace element are chemical components found in low concentrations, in mass fractions of part per million (ppm) or less, in water, organisms and soil (Akoachere *et al.*, 2019a). The presence of trace elements in groundwater comes from geogenic and anthropogenic sources (Mondal *et al.*, 2010). Geogenic sources are weathering of rocks, where the trace elements easily enter the water bodies and do not readily leach out. Anthropogenic sources come from industries, agriculture, mining, smelting (Akoachere *et al.*, 2019b). Some trace elements like Cd, Pb and Cr can be lethal to human being even at low concentration because of their tendency to accumulate in the body (Djebebe-Ndjiguim *et al.*, 2013; Tamutou *et al.*, 2013; Parmar and Bhardwaj, 2014).

The exposure to trace elements contamination and associated health risk levels of the population in Nkongsamba has not been investigated thus; the measurement of trace metals for suitability of the groundwater resources for drinking, domestic and agro-industrial uses is of public health and scientific concern. This work is aim at characterizing trace elements concentration from the aquiferous formation in Nkongsamba. The results obtain will established; the health hazard and pollution indices of trace elements in groundwater and provide baseline on trace elements in the groundwater for future reference. The trace elements consider for these studies are: Ba, Fe, Zn, Mn, Sr, Ni, Cu, Co, Pb, Cr, As, Li, Cd and V.

1.2 Location of study and Geology

Nkongsamba is found in the Moungo Division, Littoral Region of Cameroon and lies between latitude 4.88 to 5.04N and longitude 9.8 to 10.0E (figure 1). The study area is made up of volcanic rocks which are ringed with plutonic rocks (Neba *et al.*, 1999), with basement rock dominantly gneiss and granites (figure 2) that date to Precambrian period covered with basalt (Neba *et al.*, 1999). The area lies along the Cameroon volcanic line (CVL) and consists of mountain ranges and volcanoes made of crystalline and igneous rock. The CVL is a 1600 km long chain of Cenozoic volcanic and sub-volcanic complexes that straddles the continent–ocean boundary and extends from the Gulf of Guinea to the interior of the African continent (Cantagrel *et al.*, 1978). The crystalline basement of the study area forms part of the CVL which is mobile belt between the West Africa and Congo Cratons and comprises Pan-African granitic rocks (Lassere, 1978) dating back to the Middle Proterozoic Nd model ages (Toteau *et al.*, 19). The NE-SW trend of the CVL is an indication of volcanism in the oceanic section (Lee *et al.*, 1994). Ages of silicic volcanic rocks (40Ar/39Ar) from the continental sector (Marzoli *et al.*, 1999) suggest NE–SW migration of the volcanism from Mt Oku (25 Ma) to Mt Bambouto (18–16 Ma) with the study area sandwich between Mt Manegueba and Mt Bambouto. In the volcanic region of Cameroon, the lava flow rocks are extensively used for building trade and civil engineering.

The climate in the study area is of equatorial type, with two equal seasons of amplitude. It is characterized by two annual seasons; a rainy season spanning from end February to November, an annual rainfall of 2350mm per year with maximum precipitation in August and September and dry season running from November to March, with thermal amplitude varying from 30^0C to 40^0C, precipitation depths of 2400mm (Tazen *et al.*, 2013).

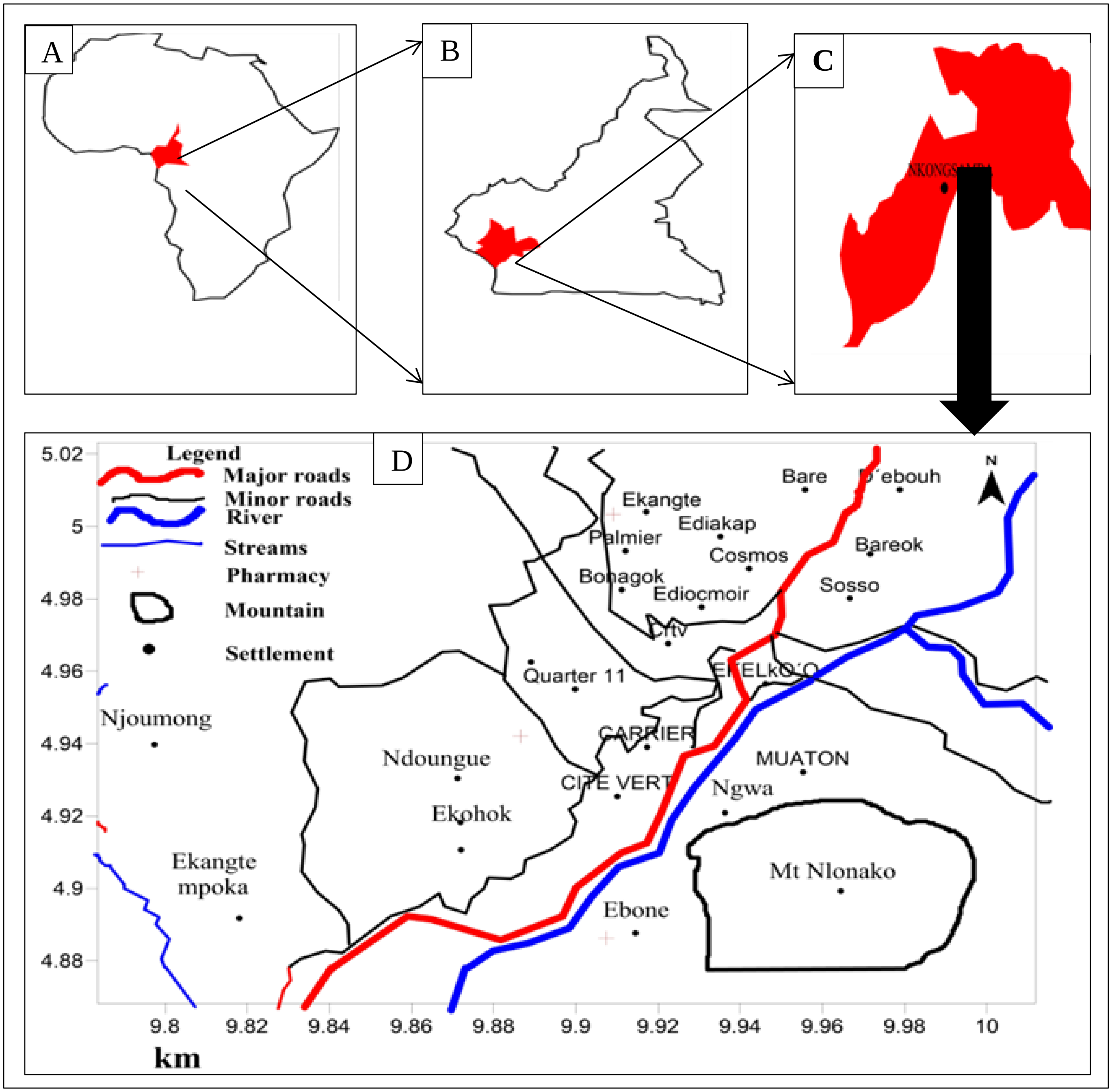


Figure 1: Location map of the study area

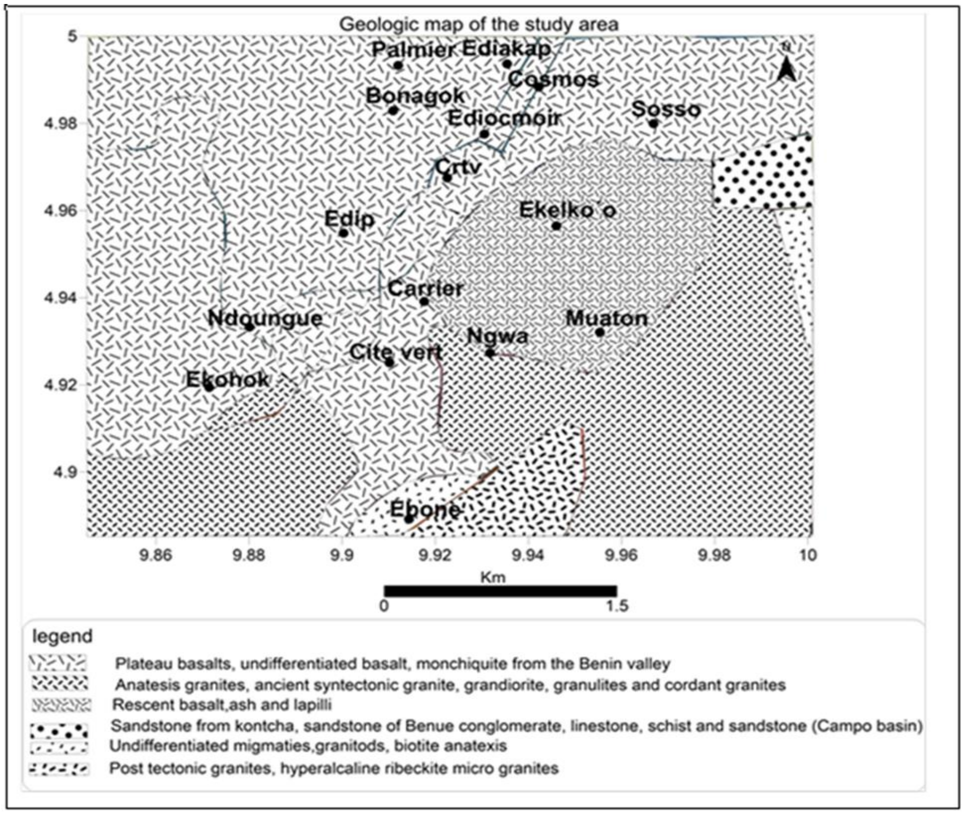


Figure 2: Geologic map of the study area

2.1 Materials and Methods

2.1.1 Field Measurement

Base on spatial distribution of wells, boreholes, springs and population, 10 water samples were collected from pre-selected wells, boreholes and springs. At each site, the groundwater temperature, electrical conductivity, total dissolve solids and pH were measured using a potable field pH, EC and TDS meters as shown in Table 1.

Leading to sampling, sample bottles were rinsed with the sample water. With the use of a 50 ml syringe, the well water was withdrawn and then filtered through the 0.2 μ m mixed cellulose ester filter into 50ml high-density polyethylene HDPE containers.

2.1.2 Laboratory Analysis

The samples were preserved using nitric acid by acidifying to pH <2 and sealed using a permanent tape. The samples were labeled and put into the sample bottle collection bag. The filtered groundwater samples were later shipped to the Activation laboratory in Canada for trace elements analysis by Inductive Coupled Plasma Mass Spectrometer ICP-MS.

Table 1: Field Equipment, Softwares, their specifications and functions used in the study

Equipment/Softwares	Specifications	Functions
Bike	Commercial Bikes (Bensikin)	To transport to wells
GPS	GARMIN GPSMAP 60 csx	To measure longitude, latitude and elevation of wells
EC Meter	Hanna Hi 98304/Hi98303	To measure Electrical Conductivity of water
pH Meter	Hanna Hi 98127/Hi98107	To measure pH of water.
Measuring Tape	Weighted Measuring Tape	Measurement of well diameter and depth.
Digital Thermometer	Extech 39240 (−50˚C To 200˚C)	To measure water temperature
Total Dissolved Solid	Hanna HI 96301	To measure Total dissolved solids
Water sampler	Gallenkampf 500 ml	To collect water sample from well
Syringe	50 Ml, 100 Ml Polystyrene	Acidification and filtration of sample
Nitric acid	98% Pure Nitric Acid	Sample preservation by acidifying to pH < 2
Filter	Cellulose Ester Filter 0.2 μm	Filtration of sample
Sample bottles	Polyethylene (HDPE) 50 ml	To hold sample for onward transmission to laboratory
Sealing Tape and bold marker	Permanent Tape and marker	Sealing of sample bottle and labeling for transmission to the laboratory
Sodium chloride	-	Conservative tracer.
IBM SPSS Statistics	Version 25.0	Statistical analysis for PCA
Global Mapper	Version 11	GIS Geolocation of wells
Surfer Golden	Version 12	GIS plotting contours for spatial distribution
Software	Version 15	Analysis and interpretation of water chemistry
Aqua	Version 2.1.8	Production of location map
QGIS		

2.3 Hazard identification

It involves the identification of chemical of concern causing the hazard, analyze and evaluate the risk associated with that hazard and determine appropriate ways to eliminate the hazard. It also involves the characterization of potential contaminants and their relative mobilities（Paustenbach, D.J. 2002) as shown in Table 2.

Table 2: Trace elements and their effects (Akoachere *et al.*, 2019c)

Component	Toxicity effects
Zn	Zinc suppresses copper and iron intake causing peripheral neuropathy.
Co	Active in vitamin B12 and in chemical reactions. Excess causes hearth failures.
Cu	Excess leads to acute gastrointestinal problems
Cr	Excess may result in renal failures. Excess of Cr+6 is carcinogenic.

Mn	Manganese toxicity result in neurological disorder (manganism) with symptoms of tremors
Cd	Cadmium compounds are known human carcinogens.
V	Vanadium causes albumin in urine
Ni	Nickel is carcinogenic and causes neurological deficits
As	Arsenic causes cancer of the skin, lungs, liver and bladder.
Sb	Antimony causes gastrointestinal problems, kidney damage or liver damage
Al.	Aluminum causes neurotoxicity.
Pb	Lead is a carcinogen affecting every organ and system in the body
Ni	Nickel is carcinogenic and causes neurological deficits
As	Arsenic causes cancer of the skin, lungs, liver and bladder.
Sb	Antimony causes gastrointestinal problems, kidney damage or liver damage

2.4 Health risk indices

Table 3: Parameters and formulae of health risk indices for trace elements

Health risk indices	Formulae	References
Average Daily Dose (ADD)	$\mathrm{ADD} = \frac{\mathrm{C} \cdot \mathrm{IR} \cdot \mathrm{ED} \cdot \mathrm{EF}}{\mathrm{BW} \cdot \mathrm{AT} \cdot 360}$	(Hu, X., Zhang, 2012)
Carcinogenic risk assessment (CR)	CR = ADD*SF	(Kamunda *et al.*, 2016)
Non carcinogenic risk assessment or Hazard quotient (HQ)	$\mathrm{HQ} = \frac{\mathrm{ADD}}{\mathrm{RfD}}$	(Song *et al.*, 2006)
Hazard index (HI)	$\mathrm{HI} = \sum_{i=1}^{n} \mathrm{H}Q_i$	(Song *et al.*, 2006)

Table 4: Input parameters to characterize the ADD value (Wongsasuluk *et al.*, 2014)

Exposure parameters	Symbols	Units	Value
Concentration of water	C	mg/l	Table?
Ingestion rate	IR	L/day	2.2
Exposure frequency	EF	Days/years	365
Exposure duration	ED	Years	70
Body weight	BW	Kg	70
Average time	AT	Years	25,550 days

2.5 Pollution risk evaluation indices

Generally, pollution indices are estimated for a specific use of the water under consideration. The trace element degree of contamination (DC), Contamination factor (CF), enrichment factor (EF), ecological risk index (Er), potential ecological risk index (RI), pollution load index (PLI) and geo-accumulation index (Igeo) were used to evaluate pollution potential of Nkongsamba as in Table 3.

Table 5: Parameters and formulae of pollution evaluation Indices for trace elements

Trace element pollution indices	Formulae	References
Degree of contamination	$DC = \sum_{i=1}^{n} C^{i}{}_{f}$	(Boateng *et al.*, 2016)
Enrichment factor	$ER = \frac{\text{(Ci/Cie) sample}}{\text{(Ci/Cie) background}}$	(Varol *et al.*, 2014)
Ecological risk factor	$E^{i}{}_{r} = T_{r}^{i} \times C_{f}^{i}$	(Håkanson, 1980)
Ecological risk index	$RI_{i} = \sum_{i=1}^{n} E^{i}{}_{r}$	(Håkanson, 1980)
Pollution load index	$PLI = \sqrt[n]{C_{f1} \times C_{f2} \ldots C_{fn}}$	(Usero *et al.*, 2000).
Geo-accumulation index	$I_{geo} = \log_2 [C_i / (1.5C_{ri})]$	(Varol *et al.*, 2015)

3.1 Results and Discussion

3.1.2 Physicochemical Parameters

Temperature

Temperature values of groundwater in the study area ranged from 22.4^{0}C-26.4^{0}C in the wet season and 22.5^{0}C-29.5^{0}C in the dry season. Higher values of temperature are observed at Ebone and Ekelko'o for both seasons. Lower values of temperature are observed at Ndoungue and Ngwa for both seasons. The similarity in temperatures indicates a phreatics aquifer since the groundwater temperature is closer to air temperature. This is similar to work done by (Akoachere *et al.,* 2019a) in Ekondo-Titi.

pH

pH values of groundwater in the study area ranged from 5-9.24 in the wet season and 5-9.8 in the dry season. Higher values of pH are observed at Ebone for both seasons. Lower values of temperature are observed at Ndoungue and Muaton for both seasons. pH of groundwater is classified as acidic < 5.5, slightly acidic 5.5 - 6.5, neutral 6.5 - 7.5, slightly alkaline 7.5 - 8, moderately alkaline 8 - 9 and alkaline > 9. Thus, groundwater in the study area is acidic to slightly alkaline similar to work done by (Eneke *et al.*, 2011) in the Douala basin

Electrical conductivity (EC)

EC values of groundwater in the study area ranged from 1-591u/S in the wet season and 1-109u/S in the dry season. Higher values of EC are observed at Ekelko'o for both seasons. Lower values of EC are observed at Carrier, Cite Vert, Ekangte Mpoka and Muaton for both seasons as seen in Figure 5. The high EC is due to high solute concentration in the water. This is in accordance to work done by (Akoachere *et al.*, 2019c) in Mudemba.

Total dissolved solids (TDS)

The total dissolved solids (TDS) range from 0.67-395.97 mg/L in the wet season and 0.67-70.67 mg/L in the dry. Higher values of TDS are observed at Ekelko'o for both seasons. Lower values of TDS are observed at Carrier, Cite Vert, Crtv, Muaton for both seasons as seen Figure 6. These TDS values are <500mg/L thus indicating that the groundwater in Nkongsamba and environs is fresh concurring to work done by (Akoachere *et al.*, 2018) in Bafoussam.

According to WHO (2004), drinking water standard Table 4, the temperature ranges from 22.4-26.4 °C in the wet season and 22.3.1 -29.5 °C in the dry season; indicating the groundwater in the study area are good for drinking. The pH ranges from 5-9.24 in the wet season and 5.05-9.8 in the dry season; indicate that groundwater in both seasons are not suitable for drinking. The EC and TDS values are within WHO acceptable limit. Thus, the groundwater in the study area is not suitable for drinking physico-chemically.

Table 6: Physicochemical field parameters according to WHO (2004) drinking water standard

Parameters	**Wet**			**Dry**			**WHO (2004) limits**
	Max	Min	Mean	Max	Min	Mean	
T(°C)	26.4	22.4	24.16	29.5	22.3	25.8	0-30
Ph	9.24	5	6.03	9.8	5.05	6.75	6.5-8.5
EC (μS/cm)	591	1	164.79	109	1	19.34	750
TDS (mg/L)	395.97	0.67	109.50	73.67	0.67	12.96	500

3. 2 Trace metal evaluation

Table 7: Trace elements and their concentrations (mg/l) in Nkongsamba

S/N	Li	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Pb	Ba	Cd
S1	0.001	1E-04	3E-04	0.262	0.04	0.016	0.009	0.006	0.28	0.003	0.137	0.008	0.684	2E-04
S2	0.003	4E-04	0.008	0.027	0.59	8E-04	0.059	0.002	0.06	5E-04	0.098	7E-04	0.111	7E-05
S3	0.001	9E-05	4E-04	0.248	0.01	0.007	0.005	0.005	0.07	0.002	0.076	0.001	0.314	2E-04
S4	0.001	0.001	4E-04	0.046	0.01	0.001	0.002	7E-04	0.02	3E-04	0.139	8E-04	0.134	1E-04
S5	0.0009	8E-05	5E-04	0.055	0.02	0.001	0.002	0.001	0.03	0.002	0.029	0.002	0.517	1E-04
S6	0.0009	5E-05	4E-04	0.003	0.02	8E-04	0.001	0.002	0.11	1E-04	0.016	0.001	0.02	1E-04
S7	0.0007	3E-04	2E-04	0.001	0.02	3E-04	0.001	0.001	0.02	2E-05	0.064	8E-04	0.013	8E-05
S8	0.0008	4E-04	9E-04	0.003	0.07	7E-04	0.003	0.007	0.09	9E-05	0.053	0.003	0.037	2E-04
S9	0.0006	1E-04	3E-04	0.048	0.02	8E-04	0.001	0.002	0.05	6E-05	0.017	0.001	0.059	1E-04
S10	0.0005	1E-05	4E-04	0.028	0.03	0.001	0.002	0.03	0.22	5E-05	0.019	0.001	0.03	1E-04
Max	**0.003**	**0.001**	**0.008**	**0.262**	**0.59**	**0.016**	**0.059**	**0.03**	**0.28**	**0.003**	**0.139**	**0.008**	**0.684**	**2E-04**
Mean	**0.001**	**3E-04**	**0.001**	**0.072**	**0.083**	**0.003**	**0.009**	**0.006**	**0.09**	**9E-04**	**0.065**	**0.002**	**0.192**	**1E-04**
Min	**0.0005**	**1E-05**	**2E-04**	**0.001**	**0.01**	**3E-04**	**0.001**	**7E-04**	**0.02**	**2E-05**	**0.016**	**7E-04**	**0.013**	**7E-05**

Health risk indices

These health risk indices include Average daily dose (ADD), Carcinogenic risk (CR), Non-carcinogenic risk or hazard quotient (HQ) and Hazard Index (HI). Carcinogenic and non-carcinogenic risks were calculated from the ADD

Average Daily Dose (ADD)

The average daily dose in the study area ranges from 3.14286×10^{-07} to 0.0214971, with Ba and Fe having the highest values of ADD as in Figure 3. This is an indication that Ba and Fe is the highest daily intake of all the elements in the study area. All the trace elements fall within the acceptable limits for average daily dose. This is in accordance to work done by (Akoachere *et al.*, 2019a) in Ekondo-Titi and (Akoachere *et al.*, 2019d) in Douala.

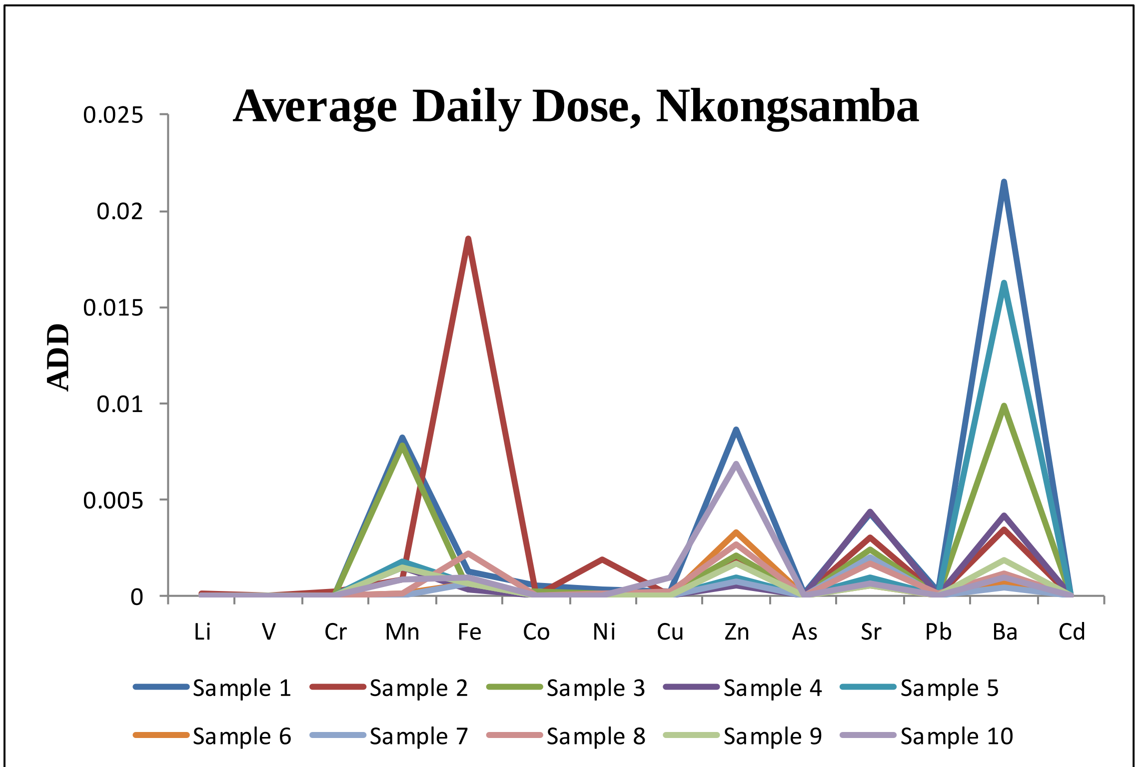


Figure 3: The average daily dose of trace elements in water samples of Nkongsamba

Carcinogenic risk Assessment

The carcinogenic elements; As, Cr, Cd and Ni. They range from (As) $1.3011\text{x}10^{-05}$ to 0.00221845, (Cd) 0.00001848 to 0.00005808, (Cr) 0.000352 to 0.013728 and (Ni) $3.7714\text{x}10^{-05}$ to 0.0022176 as seen in Figure 4. All trace metals and below permissible limits thus consumption of the groundwater over time will not pose any health issues to the inhabitants of the study area. This is in accordance to work done by (Akoachere *et al.*, 2019a) and (Akoachere *et al.*, 2019d) in Ekondo-Titi and Douala respectively

Non- Carcinogenic or Hazard Quotient (HQ)

The non-carcinogenic elements are; V, Mn, Fe, Cu, Zn and Pb. They ranged from; (V) $4.4898\text{x}10^{-05}$ to 0.005836735, (Mn) 0.003142857 to 0.588163265, (Fe) 0.00044898 to 0.026489796, (Cu) 0.00055 to 0.023728571, (Zn) 0.001791429 to 0.028809524, (Pb) 0.006285714 to 0.074440816. The HQ values were all found to be <1 using the USEPA, 2012. This result is indicative of no carcinogenic adverse effects as seen on Figure 5. This is in accordance to work done by (Akoachere *et al.*, 2019b) in Mamfe and (Akoachere *et al.*, 2019d) in Douala respectively

Hazard Index (HI)

The values ranged from 0.001445 to 0.021261. The HI values for the trace element in Nkongsamba are below the permissible limits that <1 as seen in Figure 6. This is in accordance to work done by (Akoachere *et al*., 2018) in Bafoussam and (Ako *et al*., 2011) in Mbanga.

Table 8: Classification of health hazard assessment carcinogenic and non-carcinogenic Risk

INDEX	Range	Classification
Carcinogenic	$<10^{-6}$	Cause no significant health effects
	10^{-6} to 10^{-4}	Generally satisfactory
	$>10^{-4}$	Intolerable
Hazard Quotient	<1	Acceptable level (no concern)
	>1	Carcinogenic adverse effects
Hazard Index	<1	Safe
	>1	Unsafe

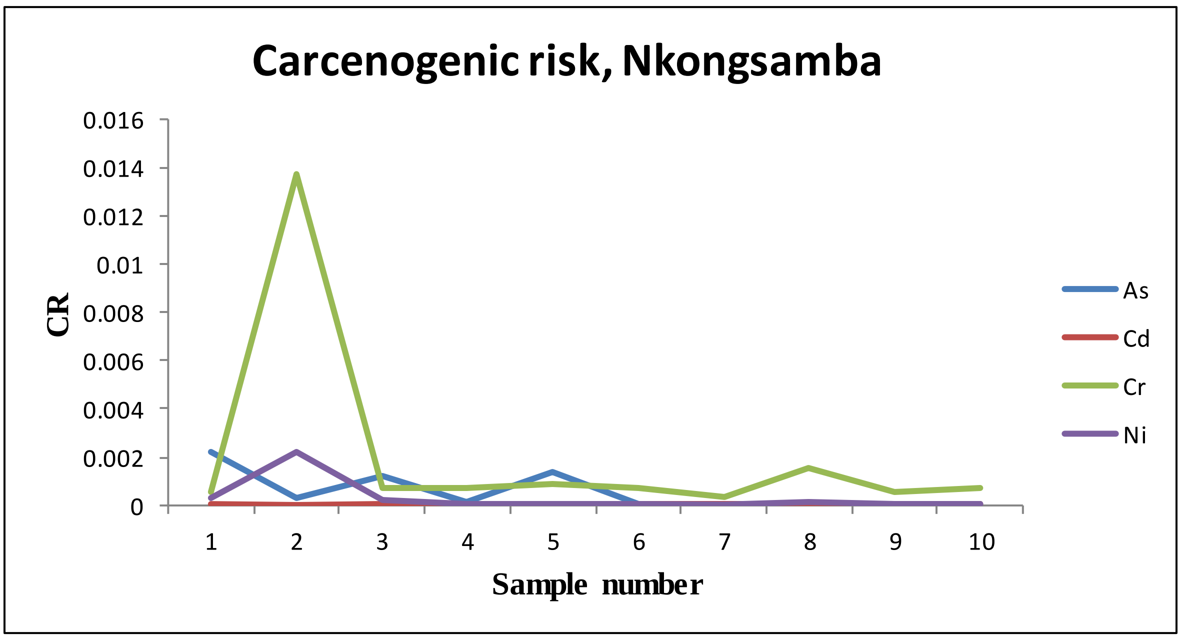


Figure 4: The Carcinogenic risk indices of trace elements the water samples of Nkongsamba

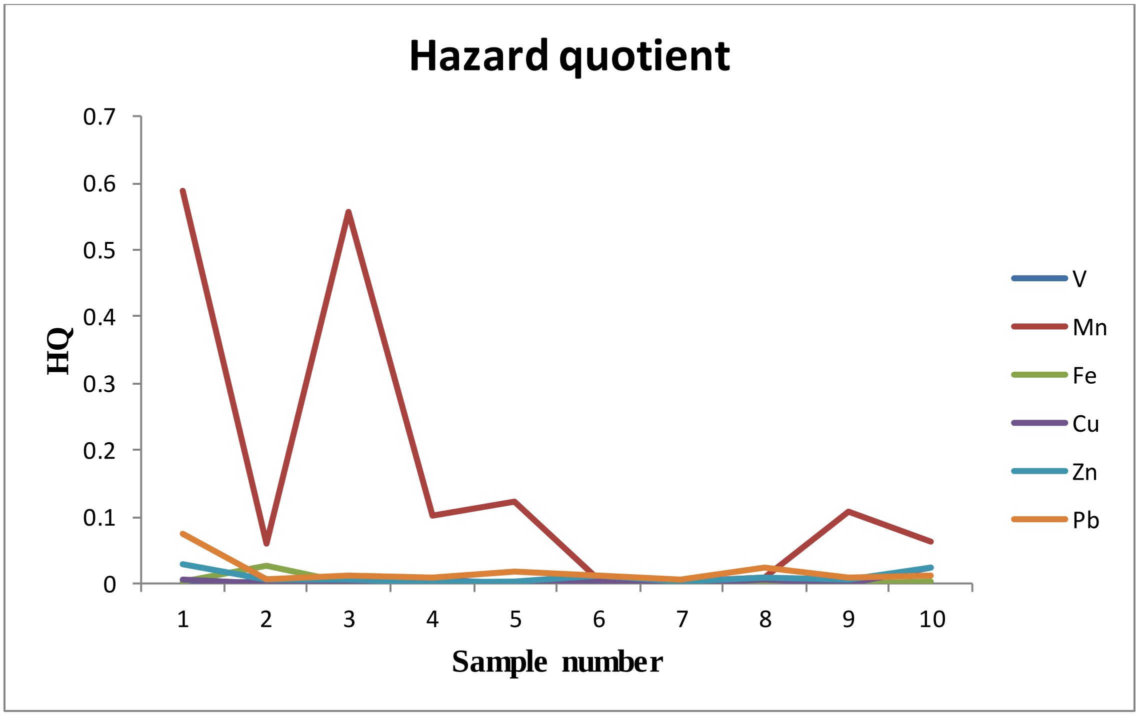


Figure 5: The Non-carcinogenic risk indices of trace elements in water samples of Nkongsamba

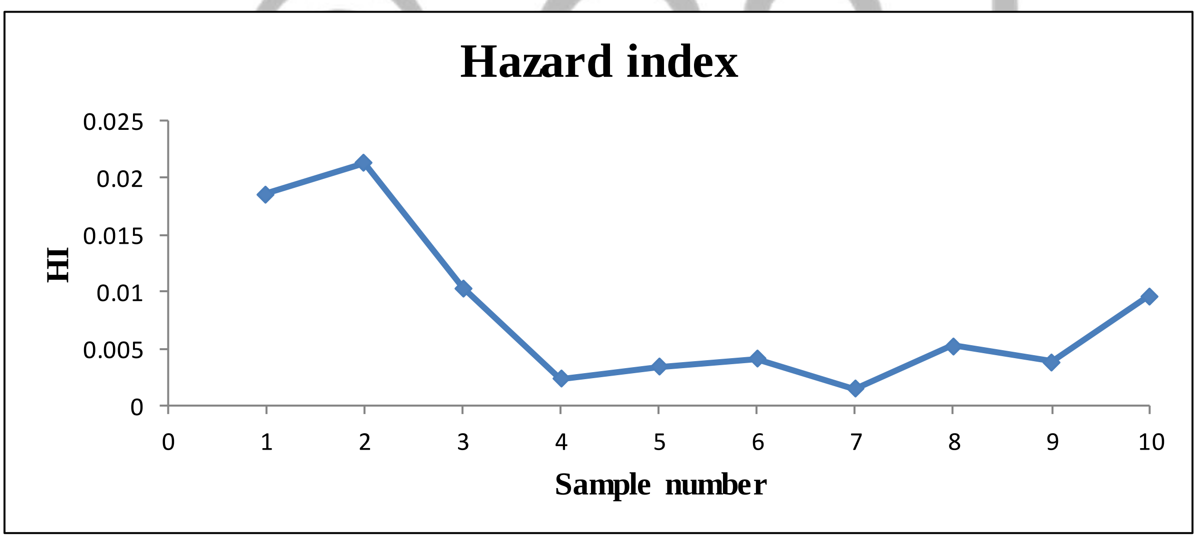


Figure 6: The Non-carcinogenic risk indices of trace elements in water samples of Nkongsamba

3.1.2.1 Pollution evaluation indices

Degree of Contamination (DC)

DC is used in estimating the extent of metal pollution. DC values in the groundwater ranges from 1.29 to 18.82. 90% of the Sample had DC factor <10 which is an indication of a low contamination whereas 10% of the sample had DC factor between 10-20 thus indicating moderate contamination Figure 7 and Table 10. This similar to work done by (Ako *et al.*, 2011) in Mbanga and (Endeley *et al.*, 2001) in Buea

Enrichment Factor (EF)

EF in the study area ranges from 0.002 to 2.61 as seen in Figure 8, indicating the source of water is from natural and anthropogenic processes Table 10. Zn is the most enriched elements in the study area; this could be attributed to agricultural and industrial waste. The sequence of EF in the water sample was Zn>Fe>Cu>Mn>Li>V>Ni>Cr>Sr>Co>Cd>As>Pb. This is in accordance to work done by (Ako *et al.*, 2014) in Buea and (Akoachere *et al.*, 2018) in Bafoussam

Ecological risk assessment

All analyzed trace elements showed low potential ecological risk that is ER<40 (Table 10). It varied from 0.012 to 13.817 as seen Figure 9A. Ecological risk index (RI) of the studied trace elements ranged from 1.767 to 26.753 as seen in Figure 9B. All analyzed trace elements for RI showed low ecological risk assessment that is <150 (Table 10). This is in accordance to work done by (Ako *et al.*, 2014) in Buea and (Akoachere *et al.*, 2018) in Bafoussam

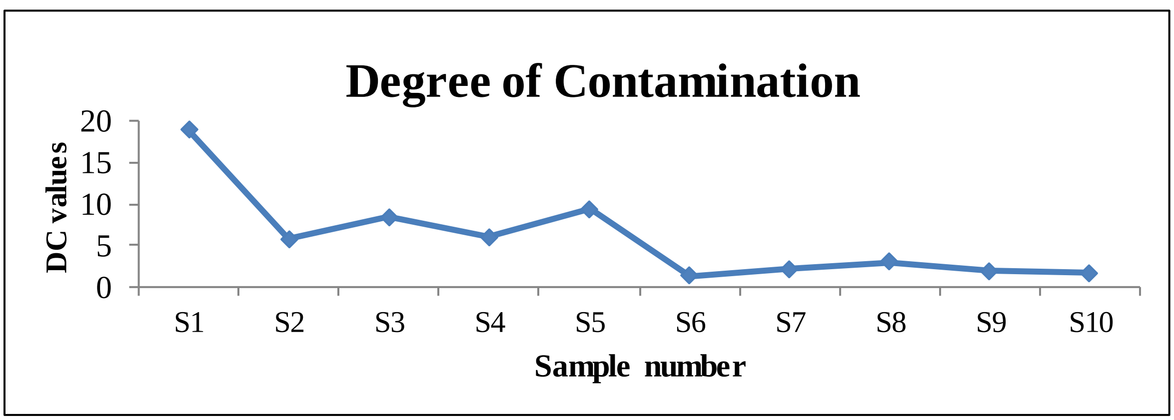


Figure 7: The degree of contamination of trace elements in the water samples in Nkongsamba

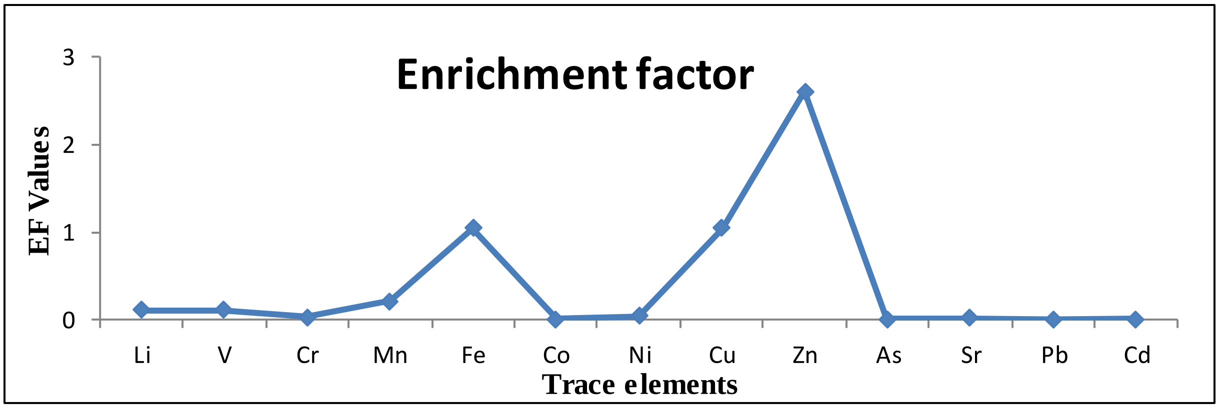


Figure 8: The enrichment factor for trace elements in the water samples in Nkongsamba

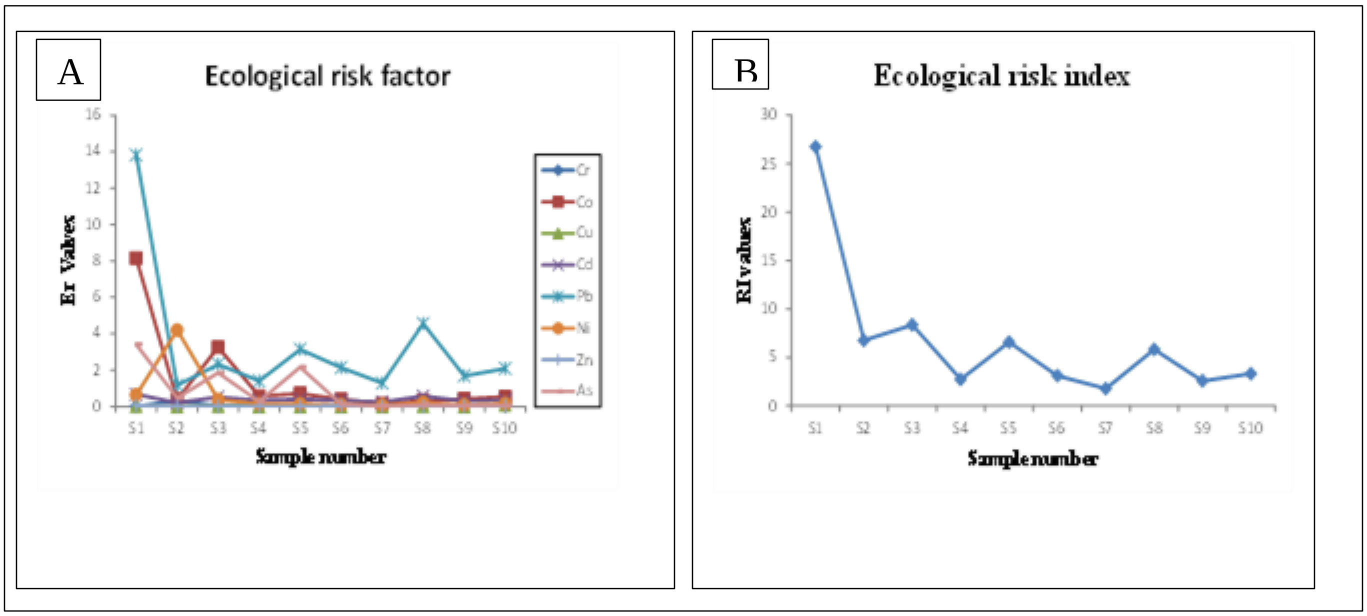


Figure 9: Ecological risk factor and Ecological risk index of trace element in Nkongsamba

Pollution Load Index (PLI)

The values varied from 0.0118 to 0.0942 as seen in Figure 10. The PLI values are <1 which is an indication that there is no pollution. This similar to work done by (Akoachere *et al.*, 2018) in Bafoussam

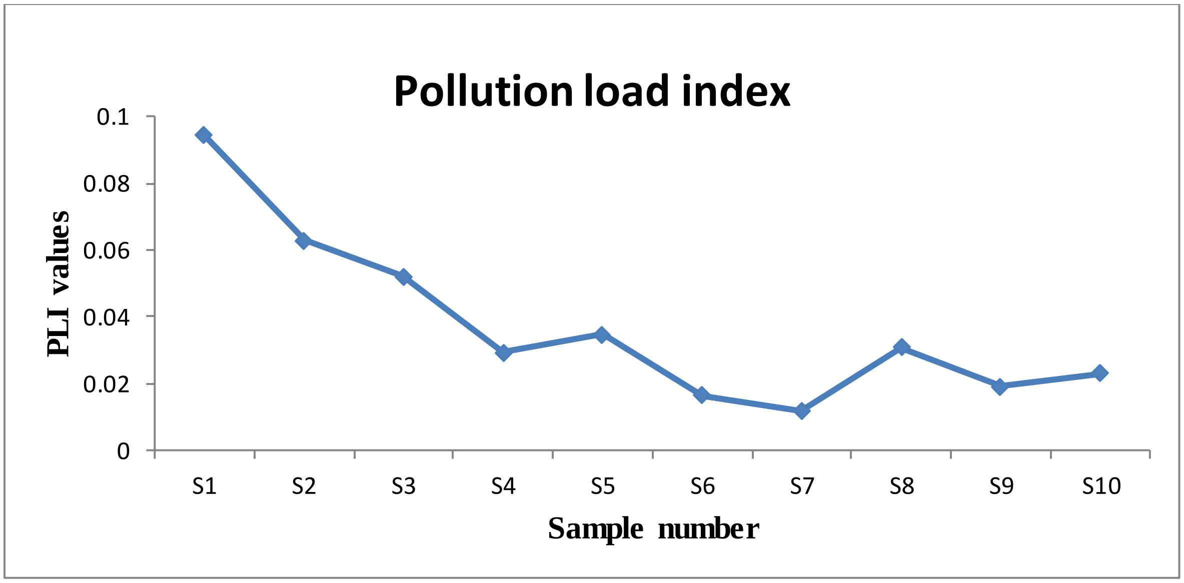


Figure 10: Pollution Load Index of trace elements in Nkongsamba

Geo-accumulation index (Igeo)

Table 9 presents the indices for the quantification of trace elements accumulation in Nkongsamba. The values varied as in Table 9. Values obtained from Igeo indicate that, the groundwater is unpolluted to moderately pollute. This is similar to work done by (Ali *et al.*, 2013) in Qadir.

Table 9: Geo-accumulation index (Igeo) of Nkongsamba

S/N	Li	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Pb	Ba	Cd
S1	-8.23	-11.55	-7.97	-1.20	-6.23	0.12	-3.56	-9.07	-4.77	-2.14	1.19	0.88	2.70	-3.32
S2	-6.64	-9.55	-3.27	-4.46	-2.35	-4.30	-0.84	-10.97	-7.05	-5.00	0.71	-2.68	0.08	-4.97
S3	-8.23	-11.70	-7.55	-1.27	-8.23	-1.20	-4.31	-9.32	-6.84	-3.02	0.34	-1.69	1.58	-3.69
S4	-8.23	-7.85	-7.55	-3.72	-8.23	-3.72	-5.71	-12.07	-8.78	-5.80	1.21	-2.42	0.35	-4.32
S5	-8.38	-11.87	-7.23	-3.44	-7.23	-3.39	-5.71	-11.17	-7.96	-2.80	-1.06	-1.26	2.30	-4.08
S6	-8.38	-12.55	-7.55	-7.74	-7.23	-4.25	-6.58	-10.55	-6.16	-6.97	-1.87	-1.81	-2.42	-4.32
S7	-8.74	-9.97	-8.55	-8.74	-7.23	-5.77	-6.71	-11.29	-8.39	-9.55	0.09	-2.55	-2.97	-4.78
S8	-8.55	-9.55	-6.38	-7.51	-5.42	-4.53	-5.13	-8.79	-6.46	-7.38	-0.19	-0.72	-1.51	-3.53
S9	-8.97	-11.55	-7.97	-3.64	-7.23	-4.18	-6.58	-10.97	-7.16	-7.97	-1.85	-2.16	-0.83	-4.46
S10	-9.23	-14.87	-7.55	-4.41	-6.64	-3.81	-5.64	-6.63	-5.10	-8.23	-1.67	-1.85	-1.82	-4.20

Maximum	**-6.64**	**-7.85**	**-3.27**	**-1.20**	**-2.35**	**0.12**	**-0.84**	**-6.63**	**-4.77**	**-2.14**	**1.21**	**0.88**	**2.70**	**-3.32**
Mean	**-8.36**	**-11.10**	**-7.16**	**-4.61**	**-6.60**	**-3.50**	**-5.08**	**-10.08**	**-6.87**	**-5.88**	**-0.31**	**-1.63**	**-0.25**	**-4.17**
Minimum	**-9.23**	**-14.87**	**-8.55**	**-8.74**	**-8.23**	**-5.77**	**-6.71**	**-12.07**	**-8.78**	**-9.55**	**-1.87**	**-2.68**	**-2.97**	**-4.97**

Table 10: Summary classification of Nkongsamba groundwater pollution evaluation indices

Index	Range	Classification	Samples	%
DC	< 10	Low degree of contamination factor	9	90
	10 – 20	Moderate degree of contamination	1	10
EF	≤ 1	Background contamination	9	90
	1 – 2	Minimal enrichment	1	10
Er	Er < 40	Low potential risk	10	100
RI	RI < 150	Low ecological risk	10	100
	<1	No pollution	10	100
Igeo	≤ 0	Unpolluted	11	78.57
	0 -1	Unpolluted to moderately polluted	2	14.28
	1 – 2	Moderately polluted	1	7.14

Pearson's correlation analysis PCA between trace elements and physico-chemical parameters

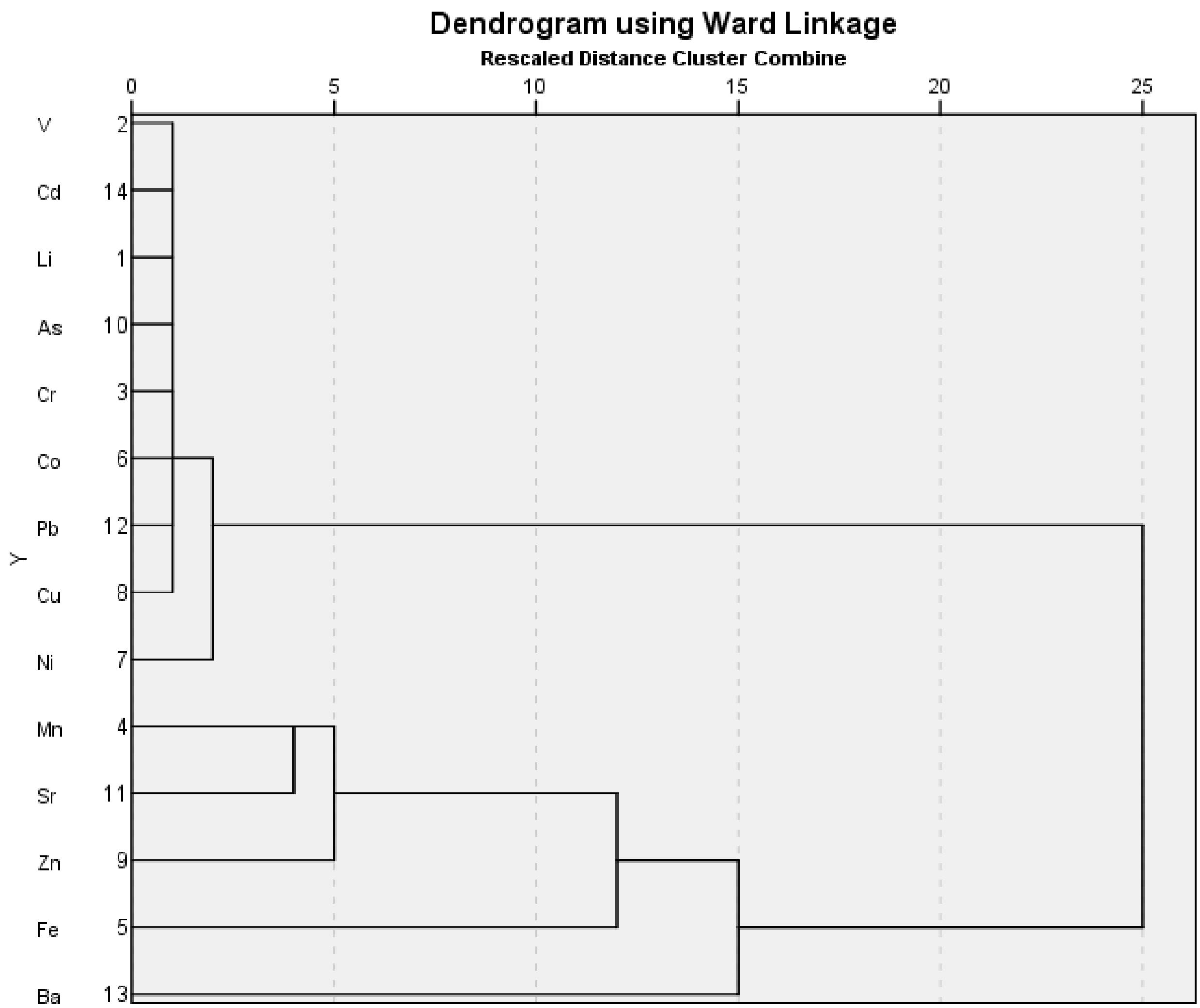
Correlation between trace elements in groundwater within the study area was carried out using Pearson's correlation analysis (PCA) as shown in table 3.5 to establish the relationships that exist between the variables; trace metals and the physico-chemical parameters. A high correlation coefficient (near 1 or 1) means a very strong positive relationship between two variables and its value around zero means no relationship between them (Varol and Davraz, 2014). Parameters showing r > 0.8 are considered strongly correlated whereas r between 0.5 and 0.8 shows moderate correlation (Manish *et al.*, 2006). The correlation matrix for trace elements in Table 11 reveals a very strong correlation between Fe/Cr (1), strong correlation between Cr/Li (0.97), Fe/Li (0.96), Ni/Li (0.98), Ni/Cr (0.99), Co/Mn (0.89), Ni/Fe (0.99), As/Mn (0.84), As/Co (0.86), Pb/Co (0.91), Ba/C0 (0.81), Ba/As (0.99), Cd/Pb (0.81) and moderate correlation between Sr/V (0.62), pH/V (0.54), Cd/Mn (0.68), Pb/Mn (0.65), Ba/Mn (0.77), Zn/Co (0.69), Cd/Co (0.75), Zn/Cu (0.62), Pb/Zn (0.74), Cd/Zn (0.58), EC/Zn (0.57), TDS/Zn (0.57), Pb/As (0.77), Cd/As (0.67), Ba/Pb (0.75), EC/Pb (0.54), TDS/Pb (0.54) and Cd/Ba (0.62).

Table 11: PEARSONS CORRELATION MATRIX FOR TRACE ELEMENTS

	Li	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Pb	Ba	Cd	Temp	pH	EC	TDS
Li	1																	
V	0.19	1																
Cr	0.97	0.12	1															
Mn	-0.02	-0.22	-0.18	1														
Fe	0.96	0.09	**1.00**	-0.17	1													
Co	-0.03	-0.22	-0.17	0.89	-0.14	1												
Ni	0.98	0.08	0.99	-0.04	0.99	-0.02	1											
Cu	-0.30	-0.31	-0.15	-0.03	-0.14	0.00	-0.15	1										
Zn	-0.16	-0.43	-0.15	0.45	-0.11	0.69	-0.06	0.62	1									
As	0.04	-0.27	-0.12	0.84	-0.11	0.86	0.00	-0.14	0.43	1								
Sr	0.40	0.62	0.24	0.48	0.24	0.55	0.33	-0.30	0.11	0.42	1							
Pb	-0.10	-0.22	-0.20	0.65	-0.16	0.91	-0.08	0.04	0.74	0.77	0.44	1						
Ba	0.03	-0.20	-0.13	0.77	-0.12	0.81	-0.01	-0.16	0.38	0.99	0.42	0.75	1					
Cd	-0.32	-0.19	-0.40	0.68	-0.38	0.75	-0.32	0.14	0.58	0.67	0.27	0.81	0.62	1				
Temp	-0.67	0.21	-0.63	-0.17	-0.65	-0.29	-0.69	-0.16	-0.37	-0.32	-0.30	-0.23	-0.26	0.03	1			
pH	0.28	0.54	0.23	-0.06	0.20	-0.23	0.23	-0.02	-0.39	-0.21	0.42	-0.47	-0.22	-0.48	-0.26	1		
EC	-0.36	-0.37	-0.29	0.22	-0.25	0.41	-0.25	0.18	0.57	0.11	-0.14	0.54	0.09	0.42	0.34	-0.75	1	
TDS	-0.36	-0.37	-0.29	0.22	-0.25	0.41	-0.25	0.18	0.57	0.11	-0.14	0.54	0.09	0.42	0.34	-0.75	**1.00**	1

Hierarchical cluster analysis of trace element

The R-mode Cluster Analysis; hierarchical cluster analysis HCA performed on the groundwater of Nkongsamba area shows two clusters based on spatial similarities and dissimilarities. The trace metals fall in two clusters: Cluster one is divided in to two classes; class one (01) element Ba; soluble and class two (4) elements Mn, Sr, Zn, and Fe; enriched. Cluster two (9) elements V, Cd, Li, As, Cr, Co, Pb, Cu, and Ni; non soluble as seen on Figure 11.



Figures 11: Dendrogram of trace elements in water samples using ward’s method

CONCLUSION

The trace elements detected in groundwater in Nkongsamba and their relative abundance in decreasing order is: Ba>Fe>Zn>Mn>Sr>Ni>Cu>Co>Pb>Cr>As>Li>Cd>V

Health risk assessment qualified groundwater in Nkongsamba as unsafe and intolerable for human consumption but without carcinogenic effects.

Pollution indices placed groundwater in Nkongsamba in the low degree background contamination with minimal enrichment, low potential ecological risk and unpolluted to moderately polluted

Very strong correlations were observed among some of the trace element pairs, suggesting common sources, mutual dependence and identical behaviour from provenance and during transport.

These low trends might not guarantee human health risks due to an increasing level of environmental pollution that might be imposed by increasing human activity in Nkongsamba; groundwater might become contaminated; this demands for monitoring of groundwater sources for drinking purposes.

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